Full Paper

Introduction

In this manuscript we report on the emerging findings from the first phase of a two-year funded research project (2015-2016) investigating the impact of integrating a flipped classroom model on undergraduate engineering student learning in a laboratory-centred, 1st-year, electronics course. Three circumstances distinguish our scenario and this study from previous work: We have a very reliable benchmark against which to assess student learning by virtue of a previous, well-funded series of innovations applied over a period of several years to tune the course that is the subject of this study; there is a strong threshold-concept emphasis in the teaching and the assessment within the course; and finally the subject paper of this investigation is a typical introductory paper with large enrolments (150 students) and five parallel laboratory streams, in contrast with the typical single-stream, 30-person, theoretically-centred course that is usually visualised when 'flipping a class' is discussed.

Background

Internationally interest is growing in the flipped classroom model of teaching and learning at the tertiary level. At the core of the flipped class are lecture-created videos or interactive lessons that are accessed ahead of class, usually through online modes of delivery to free up the class/lecture time for more constructive learning activities such as problem solving and collaborative learning (Strayer, 2012). It is argued that moving the learning materials online gives students the opportunity to decide what to watch and when thus giving them greater ownership over their learning.

Emerging evidence also exists for the value of structuring curricula around threshold concepts (Peter & Harlow, 2014). According to Meyer and Land (2003; 2006) in each academic discipline there are hard-to-grasp or threshold concepts (TCs) that students need to master in order to think and act like a subject specialist. However, students often find TCs troublesome, and this is where they often 'get stuck'. By designing their pedagogy to target the teaching and learning of specific TC content, lecturers can optimise student learning outcomes.

This research builds on our previous study which found support for the effectiveness of a TC-based pedagogy and assessment with engineering students. Students in the previous study also reported a preference for learning the course content through online tutorials that they could work through independently in their own time and pace (Peter, Harlow, Scott, Balsom, & Round, 2013). For the purposes of this paper, we focus on student evaluation of the online instructional videos created for the purposes of the TC-based flipped classroom, and the changes wrought through the replacement of lectures with these videos and with increased interactive class activities.

Flipped Classroom Learning and Online Instructional Videos

The *flipped classroom* is an innovative variant of student-centred learning with the potential to address the issues raised in the international literature regarding the need for more effective student centred learning approaches. In a flipped classroom lecture materials are usually assigned as take-home tasks, accessible through online modalities. This allows the lecturer-student class contact time to be devoted to addressing student questions and misconceptions including problem solving in teams (Strayer, 2012) and supporting the mastery of TCs (O'Toole, 2013).

Flipping the focus of class time allows students to take increased responsibility for their own learning through active investigation both in and out of class time. This changes the class time focus and dynamics from the transmission of knowledge to one involving collaborative, interactive learning and just-in-time teaching (Bonk & Khoo, 2014).

There is evidence that interactive online instructional videos can be effective in fostering university student learning (Zhang, Zhou, Briggs, & Nunamaker, 2006), including in the Engineering discipline (Anand, Chatterjee, & Bijlani, 2014) and even in the learning of TCs (Urquiza-Fuentes, Hernan-Losada, & Martin, 2014). These studies caution that simply providing students with access to instructional videos reduces the value of a flipped class approach. Rather it is how they are integrated into an overall approach that makes the difference in student learning.

Frameworks based on educational, psychological and multimedia instructional design studies describing effective characteristics of instructional videos have been proposed to guide educators keen on developing their own educational material. One such framework was developed by Mayer (2001) and elucidated by Sorden (2005). Sorden espoused that seven cognitive principles need to be considered in the development of instructional videos: signaling effect, modality effect, coherence effect, redundancy effect, multimedia effect, personalization effect, and the pacing effect. Signalling reduces a viewer/learner's cognitive load by cueing the learner to how the video material will be narrated and organized. Modality effect pays attention to how the animation/pictures and narration are combined. The coherence principle further alerts educators to include only relevant video, animation, pictures, narration, and sounds and to avoid extraneous material. The redundancy effect cautions against combining animation and narration with printed text in ways that will visually overload the learner. The multimedia effect considers that learners learn better when animation/pictures and narration/words are combined compared to using text alone. The personalization effect emphasises that narration in videos that are conducted in a conversational style is more effective than a formal style. Finally, the pacing principle states that learners learn better when they can control the pace of video presentation. This enables them to work through the video material at their own pace - slowing or pausing the presentation if needed. These seven characteristics were considered in the development of the online educational videos in our study.

Research Context and What We Did

The 'Introduction to Electronics' course introduces first-year engineering students to several TCs and is a core undergraduate engineering paper compulsory for electronics and mechanical engineering students, and recommended for various other streams. In 2015, 145 students enrolled in the course. The material has a high level of conceptual difficulty and is regarded by many students as the most challenging paper of the semester. Much of the learning revolves around tacit knowledge and practical skills that are picked up in the lab sessions.

The organisational model for this paper has traditionally consisted of three one-hour long lectures, an hour-long tutorial session, and one three-hour laboratory session each week of the semester. It is expected that each student would attend all lectures and one of 5 parallel laboratory (lab) streams, which run once a day on each day of the week. Since 2013, the face-to-face tutorial sessions had been replaced by online tutorials allowing students to work through question sets pertaining to the course content at their own pace. The switch to online tutorials was welcomed by the majority of students, and resulted in a significant improvement in both learning and satisfaction.

Figure 1 immediately below depicts the vision for the course in traditional format and once it is fully flipped. The figure allows the identification of various organizational difficulties inherent in a multi-lab-stream delivery, and the potential impact upon these constraints of a switch to video content delivery. In the case of traditional delivery with a lab class on every day of the week and lectures spread throughout the week, it is not possible to assume in the lab classes that students have seen content until the week after it is delivered. This is portrayed by the diagonal arrows in the traditional delivery situation. This results in the need for “stand-alone labs” whose learning capacity is generally low. There are concomitantly “hanging lectures” with which no lab will be associated.

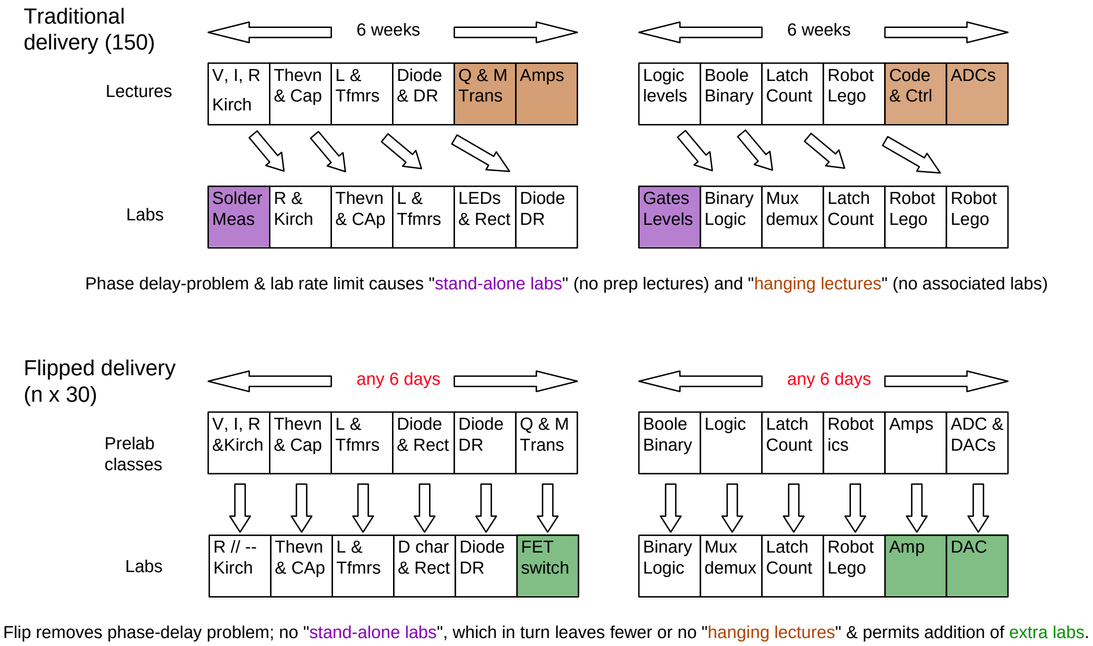

Figure 1: Course Organisation (Traditional versus Flipped)

The flipped-class delivery situation illustrates the flexibility of having self-timed acquisition of content which eliminates “stand-alone labs” and concomitant “hanging lectures” while permitting additional lab sessions.

In the A-semester component of this project we trialled a flipped-class model for only 3-weeks (weeks 2 to 4 out of the 12-week semester) by replacing the 50-minute weekly lectures with a suite of short videos, both lecturer-developed “Khan-Academy-style” videos (Khan Academy, 2015) and publically-available videos hosted on Youtube, accessible to students from the course Moodle site (Moodle is our university online learning management system). The instructional videos (typically between 4 and 13 minutes in length) targeted two TCs in the course (circuit modelling in the form of Thevenin's theorem, and linear approximation in the case of dynamic resistance). As these TCs are mostly taught using circuit diagrams, graphs, and equations, the videos recorded and allowed the lecturer to draw, modify and elaborate using a drawing tablet to replicate the way he usually teaches in his face-to-face class. Smoothdraw and Quicktime were used for the video screen capture. Sorden’s (2005) principles guided the development of the instructional videos. The videos were created or selected over a 3-month period during which the lecturer worked intensely with educational researchers and a professional video-production technician to achieve a high standard.

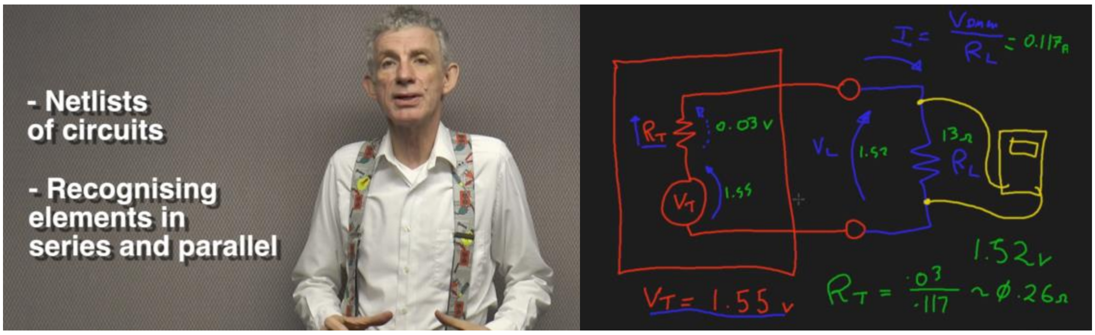

Figure 2: Screenshots from a lecturer-developed video

Altogether, by the time of the first delivery, the lecturer developed approximately 30 original videos and selected an additional 30 internet-based videos. Students were advised to watch the weekly assigned videos prior to attending the flipped class and practical labs. The weekly three-hour laboratory sessions was extended to four hours to allow for small-group problem solving activities and in anticipation of more personal instructor interaction. The expectation was that by flipping the class, students would have more opportunities to be active knowledge constructors with the lecturer facilitating students to achieve deeper levels of thinking and higher levels of knowledge application.

Research Design

A design-based research (DBR) process (Collins, Joseph, & Bielaczyc, 2004) involving practitioner-led cyclical processes of planning, design and implementation of a TC-based flipped class approach was adopted to frame the research intervention. Three cycles of intervention are anticipated over the duration of the two-year project. This paper reports on the findings from the first cycle of intervention involving a three-week trial (out of a 12 week semester) of the TC-based flipped class approach.

A mixed method approach was used to collect data through multiple sources: student focus group interviews, student surveys, observations in the flipped classroom, video analytics of student access strategies to the lecturer-developed flipped class video materials, student access and usage logs in the university learning management system (Moodle), and student achievement data. Statistical analysis was conducted on the quantitative data to ascertain differences and trends in student achievement and perspectives. Qualitative data was analysed using thematic analysis to develop themes through inductive reasoning (Mutch, 2005). Analyses of the findings are currently being undertaken and are yet to be completed.

For the purposes of this paper, we focus on student evaluation of the lecturer-developed instructional videos. The findings will provide an indicator of the merit of flipped class model and signal areas for pedagogical refinements (including instructional video development) in the second year of the project.

Findings

One hundred and fourty one students responded voluntarily to the post-intervention survey on their learning experiences. Overall achievement analysis showed that students' achievement in the flipped class section of the course in the final examination could not be predicted from their engagement with the lecturer-developed video materials.

Benefits to Learning

When asked if they had watched ‘a few videos’, ‘watched most’, ‘watched all’ or ‘did not watch any videos’ assigned to them on a weekly basis, less than half of the students reported that they had watched a few videos (44%), 39% said they watched most, 10% reported that they had watched all videos, while 7% said that they did not watch any. Overall, 93% of students reported that they had watched the assigned videos and found them to be easily accessible albeit to different extent.

A majority of students thought the length of the videos were just right (74%), 24% thought they were too long, and only 3% thought they were too short.

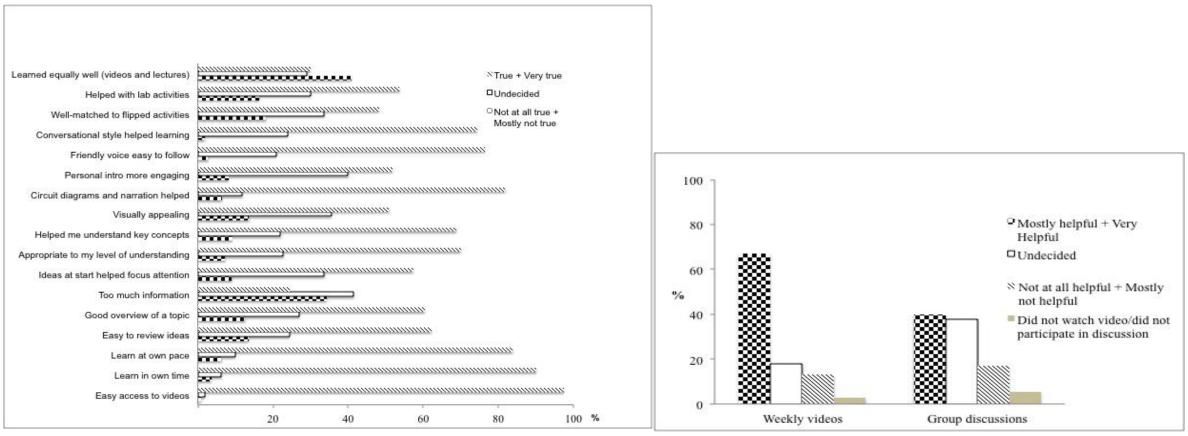

Figure 3: Student evaluation of lecturer-developed videos and comparison of their value

As can be seen in the left-hand side graph in Figure 3, combining student responses from the ‘Very True’ and ‘True’ categories, 90% of students appreciated being able to learn in their own time, 84% thought they could learn at their own pace, 90% that they could learn in their own time, while 62% thought the videos helped them to easily review course ideas. This finding attested to the value of adhering to the *pacing principle* of learning provided by the instructional videos.

A majority (60%) of students thought the videos were a good overview of a topic, slightly over half (57%) reported the ideas at the start of the videos were helpful in focusing their attention while another 24% thought the videos contained too much information. These highlight that consideration of the *signalling principle* was useful to students’ learning from the videos. The *coherence effect* was evidenced to be useful in supporting student learning when a majority reported that the videos were appropriate to their level of understanding (70%) and helped them to understand key concepts (69%). Characteristics of the video that paid attention to principles of modality, multimedia and redundancy were further useful in supporting student learning when a majority of students thought the videos were visually appealing (51%), the combination of circuit diagram illustration and narration helpful to learning (82%), and, the inclusion of the lecturer’s personal introductions to a topic at the beginning of the video more engaging (52%). Finally, almost three quarters of students thought the lecturers’ friendly voice made it easy to follow the videos (76%) and that his conversational style of narration helped their learning (74%), highlighting the importance of personalising the narration in educational videos.

The right-hand graph shows that overall, 67% of students responding affirmed the value of the lecturer developed weekly videos as helpful to their learning. Less than half however (41%) thought the videos helped them to participate in the flipped class discussions. Student response in the focus group and open-ended survey questions indicated they liked learning from the videos because “watching them was a lot easier to understand than being in a lecture”.

Overall, in terms of learning TCs, students reported that videos covering Thevenin theorem (75%) and Kirchoff's laws (83%) helpful to their learning.

Challenges to learning

However as noted in Figure 3 above, only about half of students thought the videos' content was well matched to the lab's activities (48%), and, helped their practical application in the lab activities (54%). Additionally, only 30% of students reported that they learned equally well from the videos as from attending live lectures.

Asked if they preferred flipped or traditional modes of lecture delivery about 21% of students said they preferred flipped mode, 62% said they preferred the traditional mode and 17% had no preference.

Although students reported liking the accessibility and flexibility of the videos for their learning, most of them did not watch anywhere near all of the assigned weekly videos, including ones crucial to their TC learning. The video analytics data confirmed that students were not fully engaging with the assigned weekly videos. Students' comments revealed that a lack of time/self-management (procrastination) and not having a real-life person to interact with when they have questions while watching the videos contributed to less than optimal video viewing. Key student quotes revealed:

> *keeping on top of them (watching videos) was the hard bit; it puts more pressure or more dependence on a student for their own learning* (student commentary in the focus group)

> *unable to ask a tutor or someone about something in the video* (student commentary in the open ended survey questions)

The video analytics corroborated students' video watching behavior. For example, in the final week of the flipped class intervention covering the TC learning of Thevenin's theorem, over half of the students did not watch all of the three key videos related to the topic (e.g., 61% did not watch a video titled 'Finding Thevenin Equivalent Circuit', while 54% did not watch 'Thevenin Equivalent Circuit Example'). With regards to the third video titled 'Thevenin Equivalent Circuit and Measuring It', interestingly, almost all students watched it to some degree the video (97%). Further examining of this third video revealed that it contained footage of practical activities involved in measuring Thevenin Equivalent Circuit—making measurements in the lab—which was integrated with the conceptual idea. Students found the practical demonstration "helped to exemplify the conceptual ideas" in a manner that was useful and engaging to their learning. In short, when students did watch the videos, they found them to be useful to their learning of the course in general and TCs in particular.

A key student suggestion from the focus group interview point to the potential of developing a more structured flipped class approach in which lectures are still available albeit in a reduced number each week to focus on overviewing each week's topics and pointing students to the relevant videos for detailed content. Having face-to-face support in the form of drop-in help sessions to address questions students may have while/after watching the videos is another recommendation for supporting students in the flipped class:

> *we've been so used to coming to uni and just going straight to videos would just be real scary, you don't really know what to expect, how you're going to do an [intensive exam]…So I reckon at least the first week have lectures so you just get to know, you know, who's taking the same course as you, who's teaching and that sort of stuff, and then have flipped- the videos but at the same time have the tutorials, the one-on-one tutorials early so if you do have questions that will help a lot* (student commentary from the focus group).

Discussion and Conclusion

This study investigated students' perspectives of the merits of the online instructional videos for the purposes of a TC-based flipped classroom which was trialled over three weeks in a large first-year undergraduate electronic engineering course with a strong laboratory component. Findings from the student evaluation on the whole revealed that students were generally positive about learning TCs through online instructional videos during the flipped class weeks. Apart from developing videos that are deemed to be effective, the data showed that other course design factors also come into play when implementing the flipped class.The findings thus far show that students prefer learning from a real person (teachers, demonstrators, peers) especially when they have questions related to video materials. The video analytics data reveal that students are not fully engaging with the assigned weekly videos. However, when students do watch the videos, they find them to be useful to their learning of the TC. Challenges in terms of time management was a key factor. Given the freedom to watch videos in their own time many first year students lacked the self-discipline and procrastinated, coming to the labs unprepared to participate in the group problem solving and hands-on activities.

These results suggest a need to look at revising the current strategies for motivating students to watch the videos and come to the face-to-face sessions prepared to participate. It is apparent that first year students need more initial scaffolding compared to more advanced students. Additionally, a close examination of the pedagogical characteristics and content of the instructor-prepared videos that students found particularly engaging and useful to their learning will inform our (re)design of future teaching videos and linking them more coherently with other course elements.

In terms of the organisation of the course, the switch to flipped class format essentially divides the course into 5 parallel, and potentially completely independent courses. This being the case as there is no reason for students attending any given lab stream to have any contact with students in any other stream. Potentially, they can occur on any day, and could even run simultaneously at a separate site, given available equipment, since the 5-stream arrangement is chiefly used to obtain better utilization of expensive lab space and equipment. The course, once flipped, could also be run by five separate teachers.

The lecturer-developed instructional videos proved necessary, and required no small consideration in terms of time, planning and development. This will need to be taken account by other practitioners keen to develop their own video materials, as there were inadequate online videos that were openly available targeting the teaching of TCs in the course. The selection of Youtube videos from the pool of publically available offerings identified over a large number of web searches required considerable patience and time but produced two insights. Firstly and less surprisingly, a great number of the available videos were rejected either because they were technically erroneous, or because they violated too many cognitive principles leading their difficulty holding the viewer's attention. Secondly and crucially, very few videos successfully addressed any of our identified TCs. One might even consider this scarcity as some sort of quantitative indicator of threshold nature.

In conclusion, our study has indicated there is much promise in developing videos that are guided by sound principles of learning but these on their own are inadequate in a flipped classroom context. If flipped classes are to be effective, a coherent course design that can motivate students to do their learning homework is important.

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